| **Section 25.3** | **The Universe** |
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**Key Concepts**

* [What is the size and structure of the Milky Way Galaxy?](javascript:openCrossRef('../ch25/ch25_s3_1.html%23lnk716.1'))
* [In what ways do galaxies differ from one another?](javascript:openCrossRef('../ch25/ch25_s3_2.html%23lnk717.5'))
* [What evidence indicates that the universe is expanding?](javascript:openCrossRef('../ch25/ch25_s3_3.html%23lnk719.2'))
* [According to the big bang theory, how did the universe begin?](javascript:openCrossRef('../ch25/ch25_s3_4.html%23lnk720.5'))

**Vocabulary**

* [galaxy](javascript:openCrossRef('../ch25/ch25_s3_0.html%23lnk715.1'))
* [galaxy cluster](javascript:openCrossRef('../ch25/ch25_s3_2.html%23lnk718.1'))
* [Hubble’s law](javascript:openCrossRef('../ch25/ch25_s3_3.html%23lnk719.1'))
* [big bang theory](javascript:openCrossRef('../ch25/ch25_s3_4.html%23lnk720.5'))

On a clear and moonless night away from city lights, you can see a truly marvelous sight—our own Milky Way Galaxy, as shown in Figure 16. **[Galaxies](javascript:openGlossaryWnd('e_ga_06_galaxy')" \o "ALT G, Glossary Term, link opens in new window)** are groups of stars, dust, and gases held together by gravity. There may be more than 100 billion stars in the Milky Way Galaxy alone. Our galaxy looks milky because the solar system is located within a flat disk—the galactic disk. We view it from the inside and see stars in every direction.



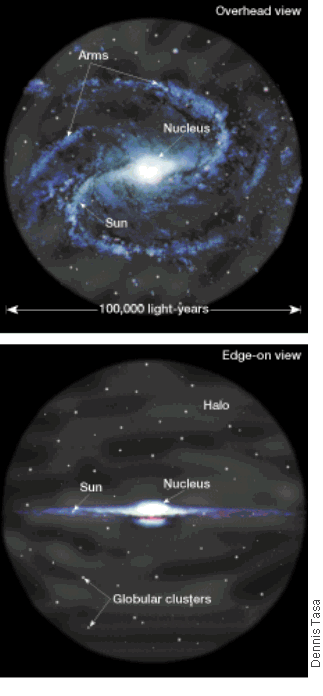
**Figure 16 Milky Way Galaxy** Notice the dark band caused by interstellar dark nebulae.

**The Milky Way Galaxy**

When astronomers began to survey the stars located along the plane of the Milky Way, it appeared that equal numbers lay in every direction. Could Earth actually be at the center of the galaxy? Scientists came up with a better explanation. Imagine that the trees in an enormous forest represent the stars in the galaxy. After hiking into this forest, you look around. You see an equal number of trees in every direction. Are you in the center of the forest? Not necessarily. Anywhere in the forest will seem to be the center, except at the very edge.

**Size of the Milky Way**

It’s hard to study the Milky Way Galaxy with optical telescopes because large quantities of interstellar matter block our vision. With the aid of radio telescopes, scientists have determined the structure of our galaxy. **The Milky Way is a large spiral galaxy whose disk is about 100,000 light-years wide and about 10,000 light-years thick at the nucleus, as shown in Figure 17A.** As viewed from Earth, the center of the galaxy lies beyond the constellation Sagittarius. Figure 17B shows an edge-on view of the Milky Way.



**Figure 17 Structure of the Milky Way A** The spiral arms are clearly visible in the overhead view of our galaxy. **B** Our solar system is located about 30,000 light-years from the galactic nucleus.

**Reading Checkpoint**

(a)How big is the Milky Way Galaxy?

**Structure of the Milky Way**

Radio telescopes reveal that the Milky Way has at least three distinct spiral arms, with some signs of splintering. The sun is positioned in one of these arms about two thirds of the way from the center, or galactic nucleus, at a distance of about 30,000 light-years. The stars in the arms of the Milky Way rotate around the galactic nucleus. The most outward arms move the slowest, and the ends of the arms appear to trail. Our solar system orbits the galactic nucleus about every 200 million years.

Surrounding the galactic disk is a nearly round halo made of thin gas and numerous clusters of stars. These star clusters do not participate in the rotating motion of the arms but have their own orbits that carry them through the disk. Although some clusters are very dense, they pass among the stars of the arms with plenty of room to spare.

**Reading Checkpoint**

(a)Where is our solar system located within the Milky Way Galaxy?

**Types of Galaxies**

In the mid-1700s, German philosopher Immanuel Kant proposed that the fuzzy patches of light scattered among the stars were actually distant galaxies like the Milky Way. Today we know that the universe includes hundreds of billions of galaxies, each containing hundreds of billions of stars. From these hundreds of billions of galaxies, scientists have identified several basic types.

**Spiral Galaxies**

As shown in Figure 18A, spiral galaxies are usually disk-shaped, with a somewhat greater concentration of stars near their centers. There are numerous variations, though. Viewed broadside, the arms are often seen extending from the central nucleus and sweeping gracefully away. The outermost stars of these arms rotate most slowly, giving the galaxy the appearance of a pinwheel.



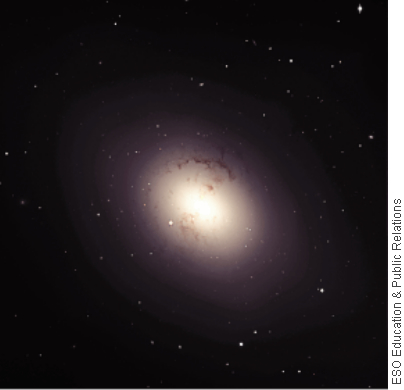


**Figure 18 Spiral Galaxies A** A spiral galaxy looks somewhat like a pinwheel. **B** A barred spiral galaxy has a bar through its center, with arms extending outward from the bar.

One type of spiral galaxy, however, has its stars arranged in the shape of a bar, which rotates as a rigid system. Attached to each end of these bars are curved spiral arms. These have become known as barred spiral galaxies, as shown in Figure 18B. Recent evidence indicates that the Milky Way may be a barred spiral galaxy. Spiral galaxies are generally quite large. About 10 percent of all galaxies are thought to be barred spirals, and another 20 percent are regular spiral galaxies.

**Elliptical Galaxies**

About 60 percent of galaxies are classified as elliptical galaxies. Elliptical galaxies range in shape from round to oval. Although most are small, the very largest known galaxies—200,000 light-years in diameter—are elliptical. This type of galaxy, shown in Figure 19, does not have spiral arms.



**Figure 19 Elliptical Galaxy** Most galaxies are classified as elliptical with shapes ranging from round to oval.

**Irregular Galaxies**

Only 10 percent of the known galaxies have irregular shapes and are classified as irregular galaxies. The best-known irregular galaxies, the Large and Small Magellanic Clouds, are easily visible with the unaided eye. These galaxies were named after the explorer Ferdinand Magellan, who observed them when he sailed around Earth in 1520. They are our nearest galactic neighbors—only 150,000 light-years away. An irregular galaxy is shown in Figure 20.



**Figure 20 Irregular Galaxy** Irregular galaxies have irregular shapes.**Describing**What type of stars would you find in an irregular galaxy?

**In addition to shape and size, one of the major differences among different types of galaxies is the age of their stars.** Irregular galaxies are composed mostly of young stars, while elliptical galaxies contain old stars. The Milky Way and other spiral galaxies have both young and old stars, with the youngest located in the arms.

**Galaxy Clusters**

Once astronomers discovered that stars were found in groups, they wondered whether galaxies also were grouped or just randomly distributed throughout the universe. They found that, like stars, galaxies are grouped in clusters. One such cluster is shown in Figure 21. Some clusters may contain thousands of galaxies. Our own cluster, called the Local Group, contains at least 28 galaxies. Of these, three are spirals, 11 are irregulars, and 14 are ellipticals. Galaxy clusters also make up huge groups called superclusters. Studies indicate that superclusters may be the largest entities in the universe.



**Figure 21 Galaxy Cluster** This cluster of galaxies is located about 1 million light-years from Earth.

**The Expanding Universe**

Recall the Doppler effect that you read about in Chapter 24. Remember that when a source is moving away, its light appears redder than it actually is, because its waves appear lengthened. Objects approaching have their light waves shifted toward the blue or shorter wavelengths. Therefore, the Doppler effect reveals whether a star or other body in space is moving away from Earth or toward Earth. The amount of shift allows us to calculate the rate at which the relative movement is occurring. Large Doppler shifts indicate higher speeds; smaller Doppler shifts indicate lower speeds.

**Red Shifts**

One of the most important discoveries of modern astronomy was made in 1929 by Edwin Hubble. Observations completed several years earlier revealed that most galaxies have Doppler shifts toward the red end of the spectrum. The red shift occurs because the light waves are “stretched,” which shows that Earth and the source are moving away from each other. Hubble set out to explain this red shift phenomenon.

Hubble realized that dimmer galaxies were probably farther away than were brighter galaxies. He tried to determine whether a relationship existed between the distances to galaxies and their red shifts. Hubble used estimated distances based on relative brightness and Doppler red shifts to discover that galaxies that exhibit the greatest red shifts are the most distant.

**Reading Checkpoint**

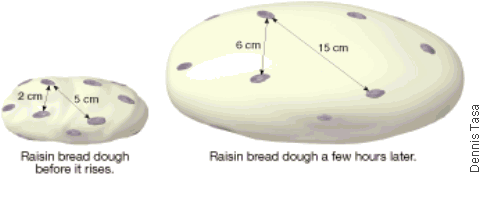
(a)What relationship did Hubble discover between red shifts and the distances of galaxies from Earth?

**Hubble’s Law**

A consequence of the universal red shift is that it predicts that most galaxies—except for a few nearby—are moving away from us. Recall that the amount of Doppler red shift depends on the speed at which the object is moving away. Greater red shifts indicate faster speeds. Because more distant galaxies have greater red shifts, Hubble concluded that they must be retreating from us at greater speeds. This idea is currently termed **[Hubble’s law](javascript:openGlossaryWnd('e_ga_06_hubbleslaw')" \o "ALT G, Glossary Term, link opens in new window)**. It states that galaxies are retreating from us at a speed that is proportional to their distance.

Hubble was surprised at this discovery because it implied that the most distant galaxies are moving away from us many times faster than those nearby. What does this mean? **The red shifts of distant galaxies indicate that the universe is expanding.**

To help visualize the nature of this expanding universe, imagine a loaf of raisin bread dough that has been set out to rise for a few hours. As shown in Figure 22, as the dough doubles in size, so does the distance between all of the raisins. However, the raisins that were originally farther apart traveled a greater distance in the same time span than those located closer together. We therefore conclude that in an expanding universe, as in the raisin bread dough analogy, those objects located farther apart move away from each other more rapidly.



**Figure 22 Raisin Dough Analogy** As the dough rises, raisins that were farther apart travel a greater distance in the same time as those that were closer together. Like galaxies in an expanding universe, the distant raisins move away from one another more rapidly than those that are near one another.

Another feature of the expanding universe can be demonstrated. No matter which raisin you select, it will move away from all the other raisins. Likewise, no matter where one is located in the universe, every other galaxy—again, except those in the same cluster—will be moving away. Hubble had indeed advanced our understanding of the universe. The Hubble Space Telescope is named in his honor.

**Reading Checkpoint**

(a)What is Hubble’s law?

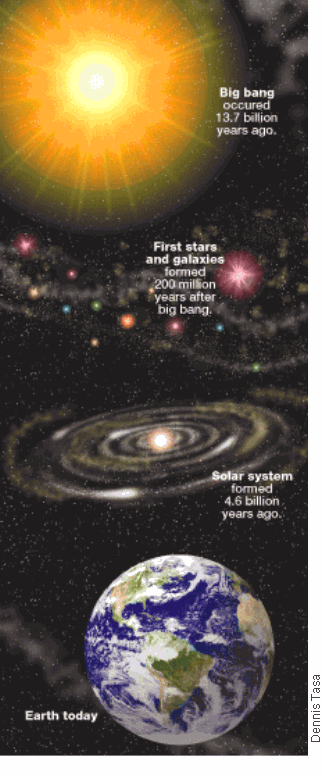
**The Big Bang**

Did the universe have a beginning? Will it have an end? Scientists are trying to answer these questions.

Any theory about the origin of the universe must account for the fact that all distant galaxies are moving away from us. Because all galaxies appear to be moving away from Earth, is our planet in the center of the universe? Probably not, because if we are not even in the center of our own solar system, and our solar system is not even in the center of the galaxy, it seems unlikely that we could be in the center of the universe.

A more probable explanation exists. Imagine a balloon with paper-punch dots glued to its surface. When the balloon is inflated, each dot spreads apart from every other dot. Similarly, if the universe is expanding, every galaxy would be moving away from every other galaxy.

This concept of an expanding universe led to the widely accepted big bang theory. According to the **[big bang theory](javascript:openGlossaryWnd('e_ga_06_bigbangthery')" \o "ALT G, Glossary Term, link opens in new window)**, the universe began as a violent explosion from which the universe continues to expand, evolve, and cool. **The big bang theory states that at one time, the entire universe was confined to a dense, hot, supermassive ball. Then, about 13.7 billion years ago, a violent explosion occurred, hurling this material in all directions.** The big bang, as shown in Figure 23, marks the beginning of the universe. All matter and space were created at that instant. After several hundred thousand years, the universe became cool enough for atoms to form. Gases in the universe continued to cool and condense. They eventually formed the stars that make up the galaxies we now observe moving away from us.



**Figure 23 The Big Bang** According to the big bang theory, the universe began 13.7 billion years ago. Two hundred million years later, the first stars and galaxies began to form.

**Supporting Evidence**

Through decades of experimentation and observation, scientists have gathered substantial evidence that supports the big bang theory. For example, the red shift of galaxies that you read about earlier indicates that the universe is still expanding. Scientists discovered a type of energy called cosmic background radiation. This energy was detected as faint radio signals coming from every direction in space. Scientists think that this radiation was produced during the big bang.

**Reading Checkpoint**

(a)What evidence supports the big bang?

**The Big Crunch?**

If the universe began with a big bang, how will it end? One view is that the universe will last forever. In this scenario, the stars will slowly burn out, being replaced by invisible degenerate matter and black holes that will travel outward through an endless, dark, cold universe. The other possibility is that the outward flight of the galaxies will slow and eventually stop. Gravitational contraction would follow, causing the galaxies to collide and combine into the high-energy, high-density mass from which the universe began. This fiery death of the universe, the big bang operating in reverse, has been called the “big crunch.”

Whether or not the universe will expand forever or eventually collapse upon itself depends on its average density. If the average density of the universe is more than its critical density—about one atom for every cubic meter—the gravitational field is enough to stop the outward expansion and cause the universe to contract. On the other hand, if the density of the universe is less than the critical value, it will expand forever. Current estimates of the density of the universe place it below the critical density, which predicts an ever-expanding, or open, universe. Additional support for an open universe comes from studies that indicate the universe is expanding faster now than in the past. The view currently favored by most scientists is an expanding universe with no ending point.

It should be noted, however, that the methods used to determine the ultimate fate of the universe have substantial uncertainties. It is possible that previously undetected matter exists in great quantities in the universe. If this is so, the galaxies could, in fact, collapse in the “big crunch.”

**SECTION 25.3 Assessment**

**Reviewing Concepts**

(1)What is a galaxy?

[**Galaxies**](javascript:openGlossaryWnd('e_ga_06_galaxy')) are groups of stars, dust, and gases held together by gravity.

(2)Describe the size and structure of the Milky Way Galaxy.

**The Milky Way is a large spiral galaxy whose disk is about 100,000 light-years wide and about 10,000 light-years thick at the nucleus;** the Milky Way has at least three distinct spiral arms, with some signs of splintering. The sun is positioned in one of these arms about two thirds of the way from the center, or galactic nucleus, at a distance of about 30,000 light-years. The stars in the arms of the Milky Way rotate around the galactic nucleus.

(3)How do galaxies differ?

About 10 percent of all galaxies are thought to be barred spirals, and another 20 percent are regular spiral galaxies; About 60 percent of galaxies are classified as elliptical galaxies. Elliptical galaxies range in shape from round to oval; Only 10 percent of the known galaxies have irregular shapes and are classified as irregular galaxies

**In addition to shape and size, one of the major differences among different types of galaxies is the age of their stars.** Irregular galaxies are composed mostly of young stars, while elliptical galaxies contain old stars. The Milky Way and other spiral galaxies have both young and old stars, with the youngest located in the arms.

(4)What evidence indicates that the universe is expanding?

**The red shifts of distant galaxies indicate that the universe is expanding.**

Recall that the amount of Doppler red shift depends on the speed at which the object is moving away. Greater red shifts indicate faster speeds. Because more distant galaxies have greater red shifts, Hubble concluded that they must be retreating from us at greater speeds.

(5)What is the big bang theory?

**The big bang theory states that at one time, the entire universe was confined to a dense, hot, supermassive ball. Then, about 13.7 billion years ago, a violent explosion occurred, hurling this material in all directions.**

All matter and space were created at that instant. After several hundred thousand years, the universe became cool enough for atoms to form. Gases in the universe continued to cool and condense. They eventually formed the stars that make up the galaxies we now observe moving away from us.

**Critical Thinking**

(6)**Comparing And Contrasting**Compare and contrast the three types of galaxies. (see question 3 above)

(7)**Inferring**If the universe is an open universe, what can you infer about its average density?

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**SECTION 25.3 Assessment**

**Reviewing Concepts**

(1)What is a galaxy?

(2)Describe the size and structure of the Milky Way Galaxy.

(3)How do galaxies differ?

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**Critical Thinking**

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